The Age of Mammals

- Cenozoic is sometimes called the "Age of Mammals."

- During Cenozoic, mammals came to dominate the Earth, much as reptiles had done during Mesozoic.

- A spectacular adaptive radiation of mammals near the beginning of the Cenozoic resulted in the appearance of mammals as diverse as bats and whales, descending from shrew-like mammalian ancestors in as little as 12 m.y.
Appearance of *Homo sapiens*

- The appearance and evolution of primates led to the ancestors of humans by the onset of Neogene.

- *Homo sapiens* appeared during Pleistocene.
• We know more about Cenozoic life than we know about life of any other span of geological time.

• This is because the fossils are better preserved and have had less time to be destroyed, they are stratigraphically highest, and usually more accessible for study.

• In addition, Cenozoic fossils more closely resemble living forms of today.
Causes of Biologic Changes

• Biologic changes during Cenozoic can be tied to changes in the environment and geographic change.
• Changes in climate to cooler and dried conditions, led to the expansion of the grasslands, which influenced the evolution of herbivorous mammals.
• Continental breakup as a result of plate tectonics, stimulated biological diversity. This resulted in distinct faunal radiations on separate landmasses, and in isolated marine basins.
Diversity of Life during Cenozoic
Recovery from the Extinctions

- At the beginning of Cenozoic, diversity was much lower than it had been during Cretaceous, as a result of the extinctions.

- **Recovery from the extinctions was rapid** (explosive), and diversity quickly climbed to a level much higher than had ever existed previously.

- Following the end-Cretaceous mass extinction, diversity of marine and terrestrial organisms increased sharply, and rose to present levels.
Eocene-Oligocene boundary

• A slight drop in diversity during Paleogene is due to an extinction event at the Eocene-Oligocene boundary, which was associated with dramatic worldwide cooling.

• Many species of marine molluscs, foraminifera, and ostracodes were affected.

• Marine organisms were affected more severely by the extinction than were terrestrial organisms.
Diversity of Life during Cenozoic

Drop in diversity at end of Paleogene
Cenozoic Plant Life

- The **flowering plants** or **angiosperms** appeared during Cretaceous, and diversified throughout Cenozoic to become the dominant vascular land plant on Earth.

- Ferns, cycads, conifers, and other plants declined relative to the angiosperms, from Cretaceous through Cenozoic.
Cenozoic Plant Life

- Holocene
- Cenozoic
- Late Cretaceous
- Early Cretaceous
Grasslands Expand and Mammals Respond

- Grasses, a flowering plant commonly eaten by grazing mammals, became widespread during Miocene.
- The expansion of the grasslands across the plains of North America and other continents was related to cooling and drying of the global climate.
- Mammals evolved in conjunction with the spread of the grasslands.
Teeth Adapt to Grasses

• Many grasses contain siliceous secretions, and because they grow close to the ground, grasses are often coated with fine particles of soil. As a result, grasses are abrasive to the teeth of grazing mammals.

• To compensate for the tooth abrasion resulting from chewing grasses, the major groups of herbivorous mammals evolved high-crowned cheek teeth that continue to grow at the roots during part of the animals' lives.
Teeth Adapt to Grasses

- The resistant enamel of the chewing teeth became infolded.
- As the teeth wore down, a complex pattern of enamel ridges became apparent on the grinding surface of the teeth.
- The incisors (front teeth) gradually aligned into a curved arc, which served for biting the grasses.
- The length of the face in front of the eyes increased in the grazing mammals to provide space for these teeth (for example, in the horses).
Limbs Adapt to Grasslands

- The limbs of grazing mammals changed to become better adapted to life on the grasslands.
- Grasslands provide few places to hide from predators, so grazing herbivores developed modifications to run more quickly.
- The bones of the limbs and feet were lengthened, strengthened, and modified by natural selection to permit rapid fore-and-aft motion, and to prevent rotation.
- The ankle was elevated, and the grazing mammals ran on their toes like sprinters.
Limbs Adapt to Grasslands

- Many grazing mammals gradually developed **hoofs** as an adaptation to protect the bones of the toes as they ran across the hard prairie sod.
- Mammals with hoofs are called **ungulates**.
- These grazing mammals also lost some of their side toes.

Evolution of the lower foreleg in horses
Cenozoic Life in the Seas
Marine Phytoplankton

- Entire families of phytoplankton became extinct at the end of Mesozoic. Only a few species in each major group survived into the Cenozoic.
- Surviving species of phytoplankton diversified rapidly during Paleogene due to decreased competition.
- Cenozoic phytoplankton include:
  - Diatoms
  - Dinoflagellates
  - Coccolithophorids
Marine Phytoplankton

- Diatoms
- Coccolithophorid
- Dinoflagellate
Marine Zooplankton

- Zooplankton diversified during Cenozoic, and became abundant in the seas. Cenozoic zooplankton include:
  - Benthonic foraminifera
  - Planktonic foraminifera
  - Radiolarians
Significance of Foraminifera

• Large benthic foraminifera resembling coins in size and shape, called *nummulitic foraminifera*, lived in the Tethys seaway and other areas. Their remains accumulated to form thick beds of nummulitic limestone, which were used to build the Great Pyramids and Sphinx in Egypt.

• *Forams are useful in correlating* rocks of Cenozoic age, particularly in oil fields around the world.
Significance of Foraminifera

- Benthonic forams can be used as water depth indicators.
Invertebrates
Dominant Cenozoic Invertebrates

- Sponges
- Scleractinian corals
- Bryozoans
- Brachiopods
- Molluscs
  - Bivalves
  - Gastropods
  - Cephalopods
- Arthropods
  - Crustaceans
  - Insects (on land)
- Echinoderms
  - Starfish
  - Echinoids
Corals

- Corals are found both as solitary types (primarily during Paleogene), and as colonial, reef-building types.

- Atolls are ring-like coral reefs that grow in shallow tropical waters around a volcano which subsides beneath the water.
Molluscs

Cenozoic molluscs are dominated by:

- **Bivalves** (clams)
- **Gastropods** (snails)
Molluscs

- **Cephalopods** are also present, but not as widespread and abundant as previously.

- Cenozoic cephalopods include the *Nautilus*, and other forms without a shell (or with a reduced shell):
  - Squid
  - Octopus
  - Cuttlefish
Echinoderms are also present during Cenozoic, particularly free-moving types (as opposed to the attached crinoids of Paleozoic). Echinoderms include the echinoids (sea urchins, sand dollars, sea biscuits), and the starfish.
Arthropods - Crustaceaceans

- Modern crustaceans (such as **crabs, shrimp, lobsters, barnacles**) became well established in the seas during Cenozoic.
Arthropods - Insects

• One of the world's best locations for fossil insects is the Oligocene **Florissant Formation**, Florissant Fossil Beds National Monument, Colorado.

• Insect fossils are preserved in fine volcanic ash which has been compressed to form shale.

• Other insects are found in amber.
Cenozoic Vertebrates

Cenozoic vertebrates include:

- Fishes
- Amphibians
- Reptiles
- Birds
- Mammals
Fishes

The bony fishes or teleost fishes thrived during Cenozoic in marine and freshwater environments.
Fishes

• Eocene fish include teleosts, the bony fishes

*Gasteronomus*, a 42-cm teleost from Eocene rocks in Italy.
Fishes

- The Eocene Green River Formation in Wyoming contains abundant well-preserved fossil fish deposited in a freshwater environment.
Sharks

- Sharks were common in Cenozoic. Sharks have skeletons of cartilage rather than of bone, and the skeletons are rarely preserved.

- Shark teeth are well preserved in Cenozoic sedimentary rocks.
Amphibians

• Cenozoic amphibians resembled modern forms. All are relatively small with smooth skin (unlike the large Paleozoic amphibians).

• Cenozoic amphibians include:
  – Frogs
  – Toads
  – Salamanders
Reptiles

Cenozoic reptiles include the following:

– Turtles
– Crocodilians
– Lizards
– Snakes
– The tuatara, the only surviving rhynchocephalian, which resembles a large lizard, and is found on islands near New Zealand.
• The turtle lineage dates back to Late Permian. Turtles have no teeth. Their jaws are covered by a beak that is used to slice through plants or animal flesh.
Crocodilians

- Crocodilians appeared during Triassic.
- Modern crocodilians include:
  - **Alligator** (broad snout)
  - **Crocodile** (narrow snout)
  - **Gavial** (very narrow snout).
Lizards and Snakes

• The lizards and snakes belong to an order of reptiles called the **squamates**.
• Lizards are the ancestors of snakes.
• Snakes are modified from lizards by the **loss of limbs**, the **change of the skull** to become more flexible to engulf prey, and the addition of more **vertebrae and ribs**.
• Some primitive snakes retain vestigial rear limb and pelvic bones, attesting to their tetrapod ancestry.
Snakes

- Snakes began to diversify during Miocene.

- Poisonous snakes evolved with specialized teeth for injecting venom into their prey.

- The diversification of snakes may be linked to the diversification of mammals, which serve as their prey.

- Fossil snakes are found in rocks as old as Early Cretaceous.
Birds

Characteristics of birds include:

1. Lightweight skeleton with thin and hollow bones
2. More neck vertebrae than most other animals (13 to 25).
3. jaws form a toothless horny beak
4. Keeled breastbone or sternum for attachment of the large flight muscles leading from the breast to the wing
Birds

5. Fused collarbone (wishbone)
6. Pelvic girdle and vertebrae are fused together to provide rigidity during flight
7. Fusion of bones of the "hand" to help support the wing
8. Four chambered heart
9. Constant body temperature
Birds

- Bird fossils are rarely preserved, so the Cenozoic fossil record of birds is poor.

- Birds have undergone **extraordinary adaptive radiation** to produce:
  - Songbirds
  - Forest birds (owls)
  - Seagoing birds
  - Wading birds
  - Flightless aquatic birds (penguins)
  - Flightless land birds (ostrich, emu)
Birds

• The fossil record is better for large flightless land birds than for small birds because they have more robust skeletons.

*Diatryma*, an Early Cenozoic flightless bird →
**Birds**

- *Diatryma*, a large flightless bird from Eocene of North America, was about 2 m tall and weighted about 300 pounds.
- It had massive legs, clawed feet, and a huge beak, suggesting that it was a **predator**.
- Others interpret it as a **scavenger** or **browsing herbivore**.